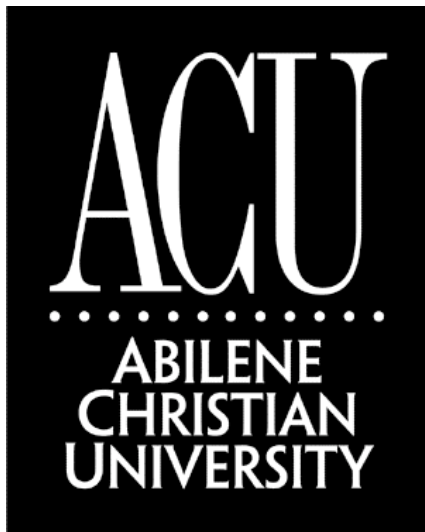


Assembly, Testing, and Installation of the Fast RPC Muon Trigger Upgrade for PHENIX

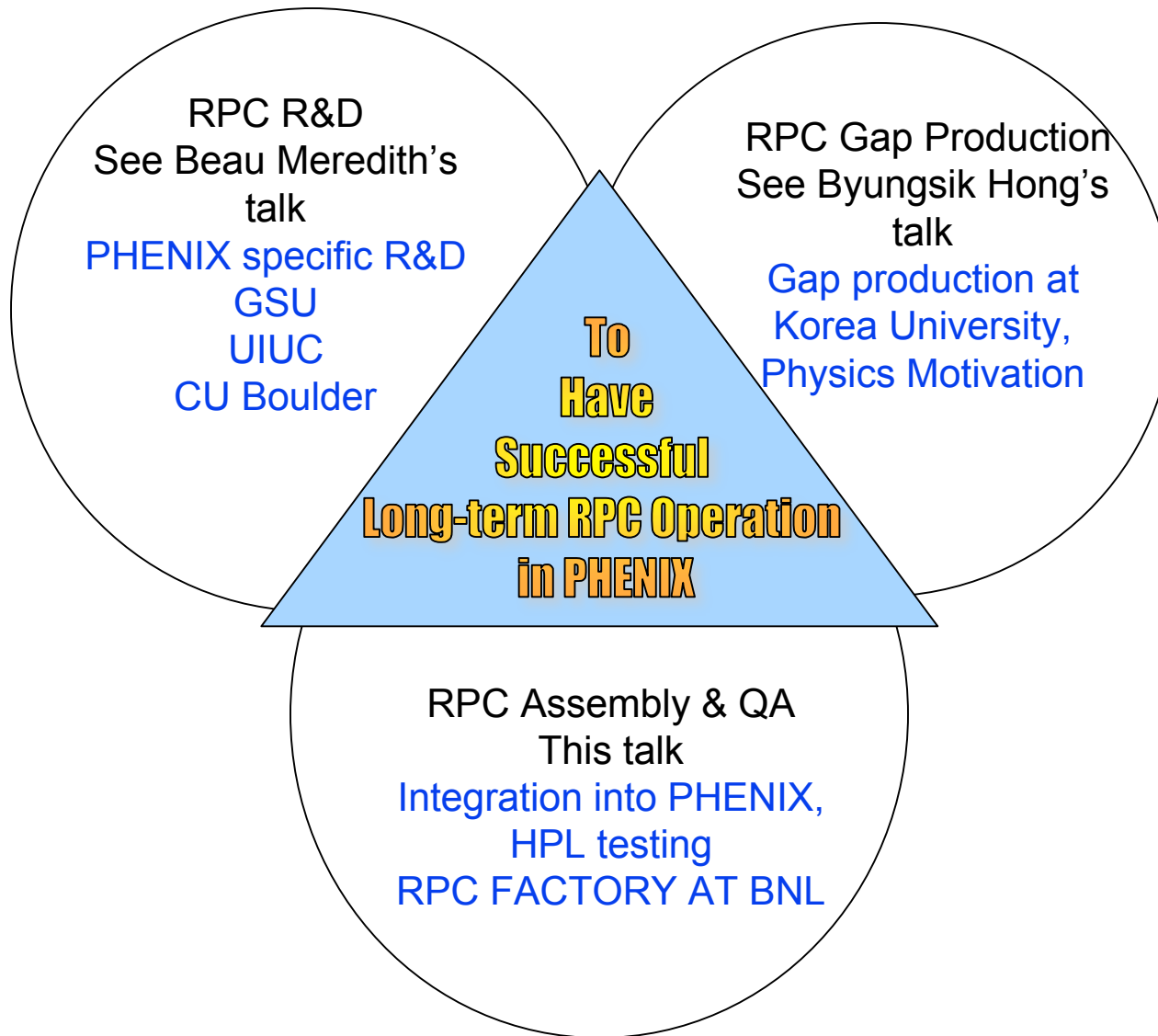
Rusty Towell of Abilene Christian University
for the



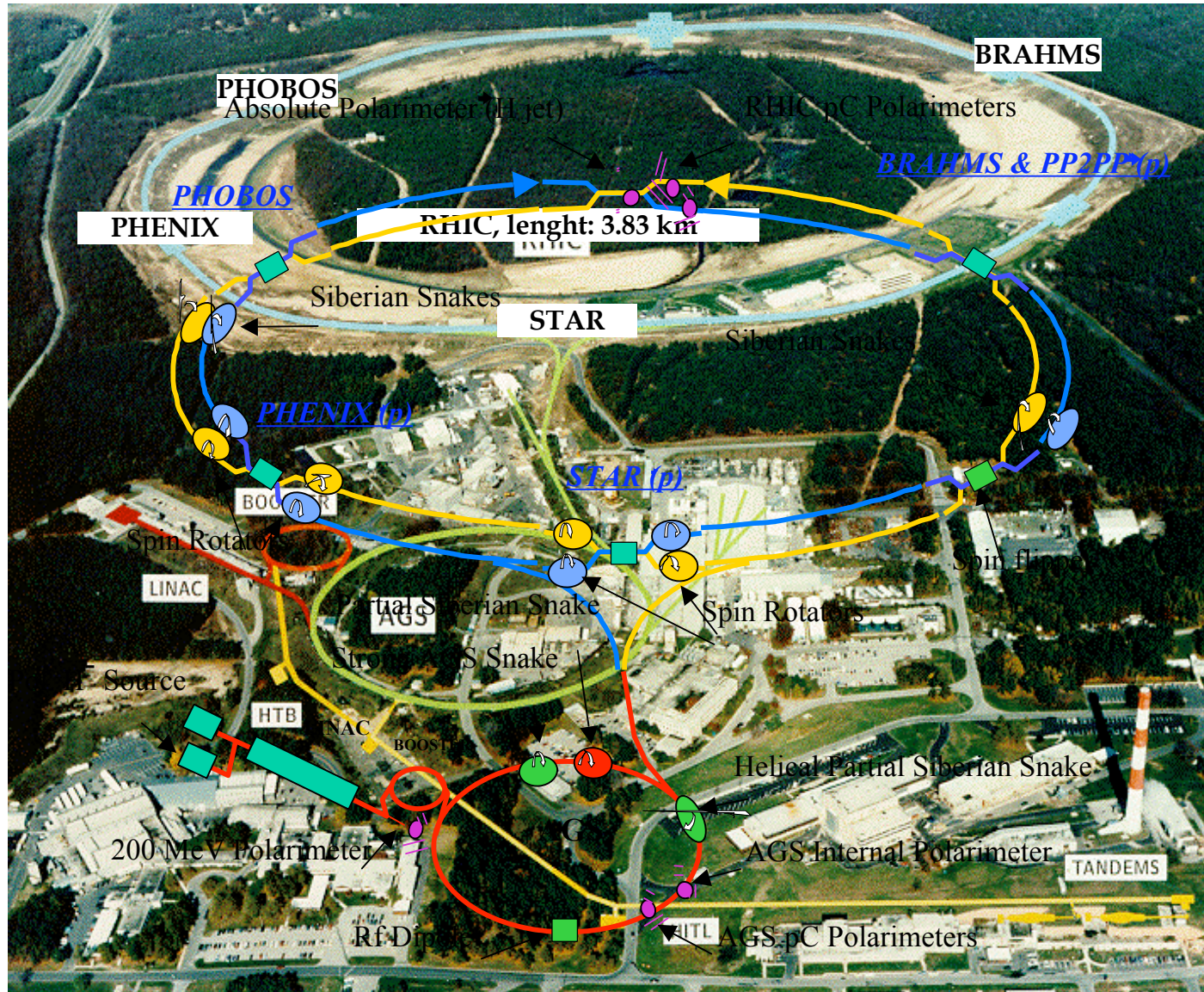
RPC2007

The IX International Workshop on Resistive Plate Chambers and Related Detectors
13 - 16 February 2008 Tata Institute of Fundamental Research, Mumbai, India

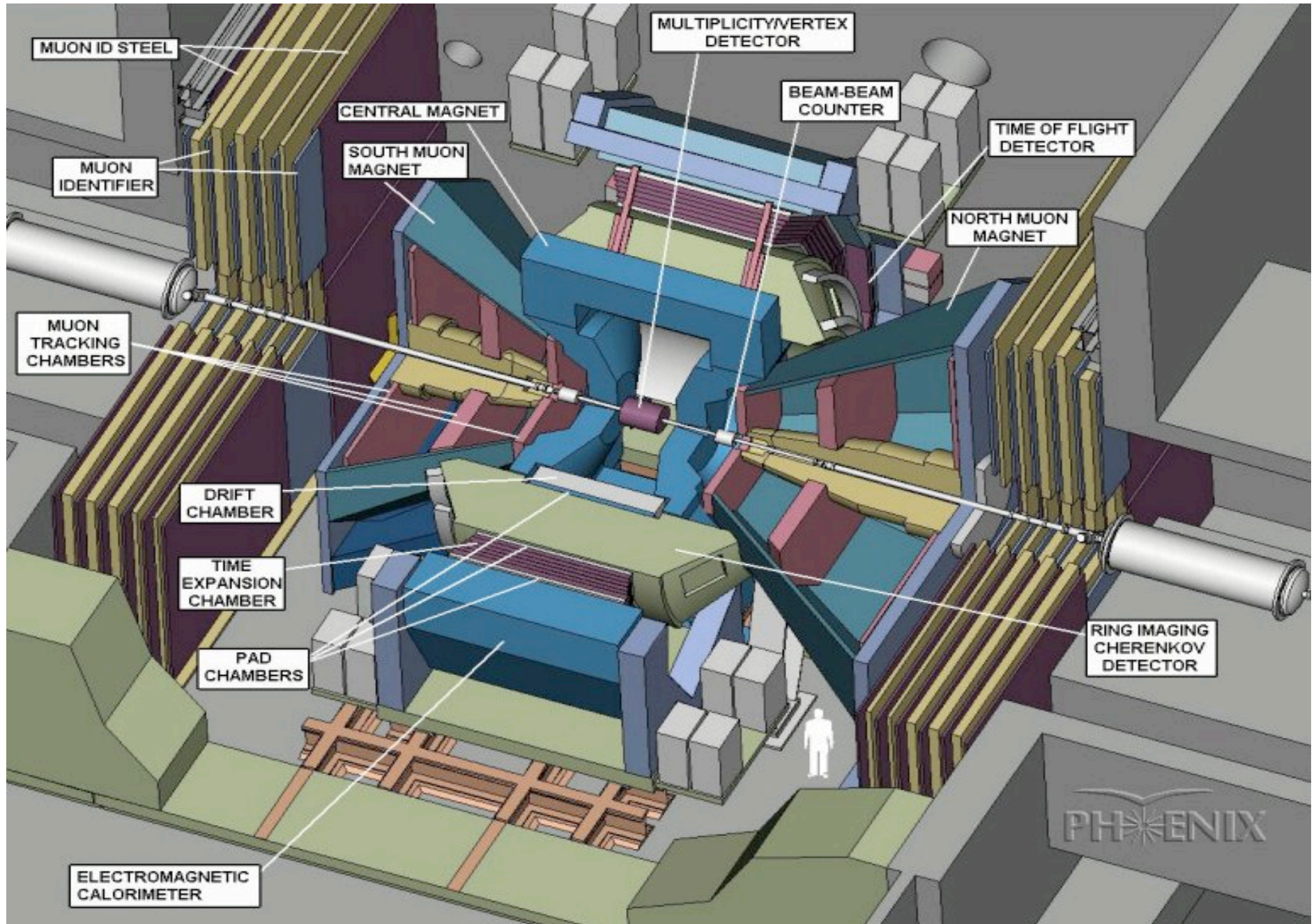
RPC Technology in PHENIX



Relativistic Heavy Ion Collider (RHIC)
also collides polarized protons



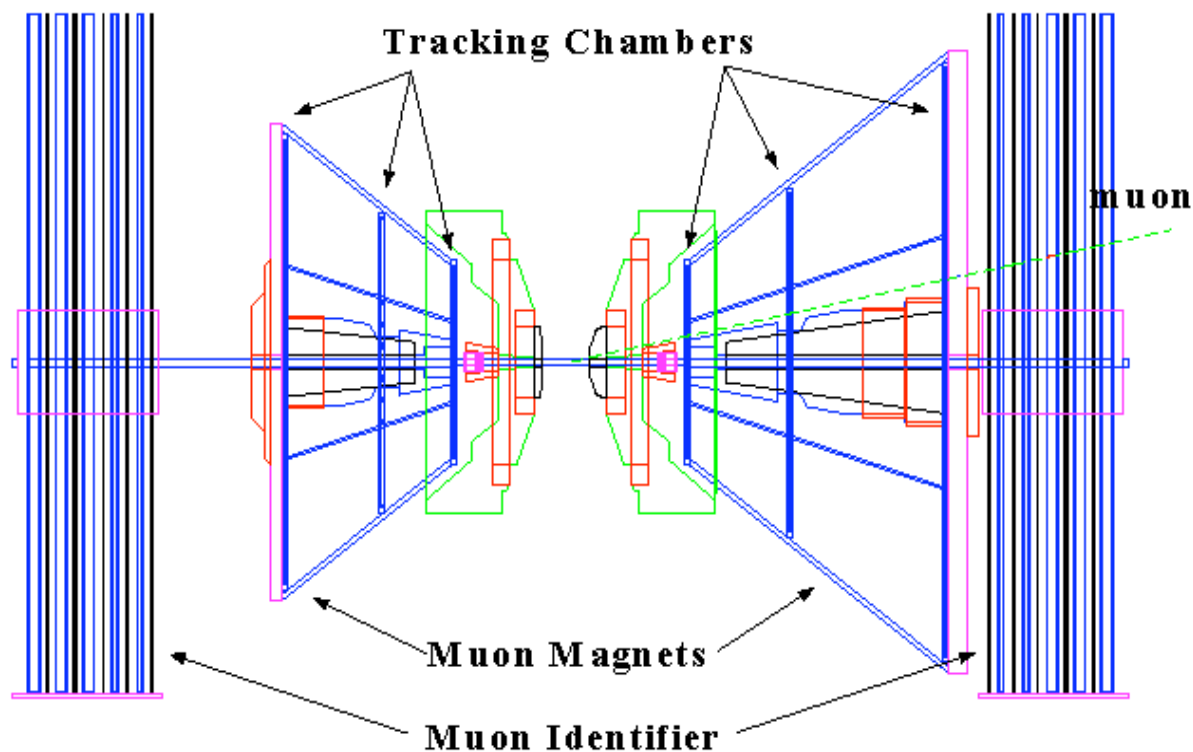
The PHENIX Detector



PHENIX Muon Arms

- Tracking with 3 stations of cathode strip chambers in magnetic field to measure the momentum of the muons.
- Muon Identification with 5 layers of chambers and steel.
- Triggering on muons using the Muon Identifier.

- Muon Arms Cover:
 - $1.2 < \eta < 2.2$ (South)
 - $1.2 < \eta < 2.4$ (North)
 - Azimuthal \sim complete
 - $p_{\text{tot}} > 2 \text{ GeV}/c$



The PHENIX Collaboration

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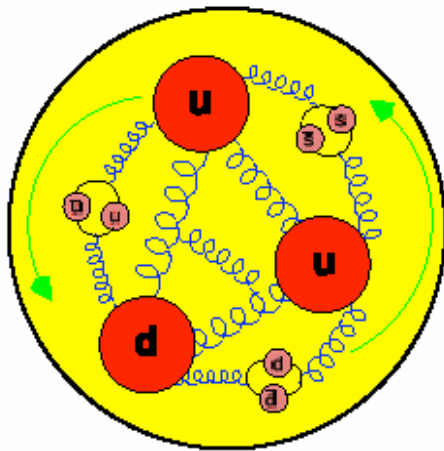
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Vanderbilt University, Nashville, TN 37235, U.S.

Motivation: The Origin of the Proton Spin

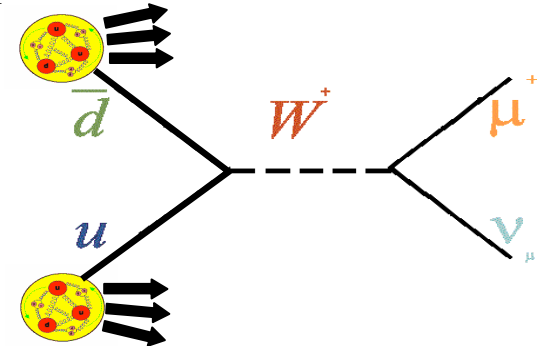


quark spin

orbital angular momentum

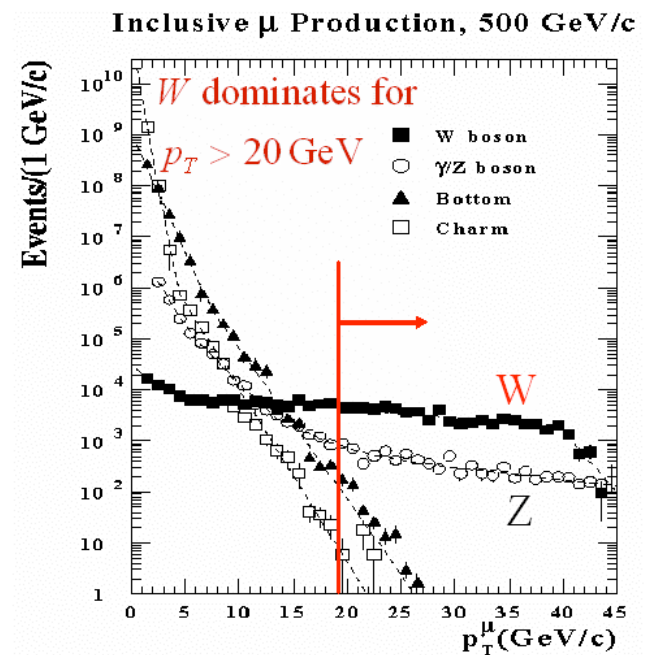
gluon spin

$$\frac{1}{2} = \frac{1}{2} \Delta\Sigma + \Delta G + L_z$$



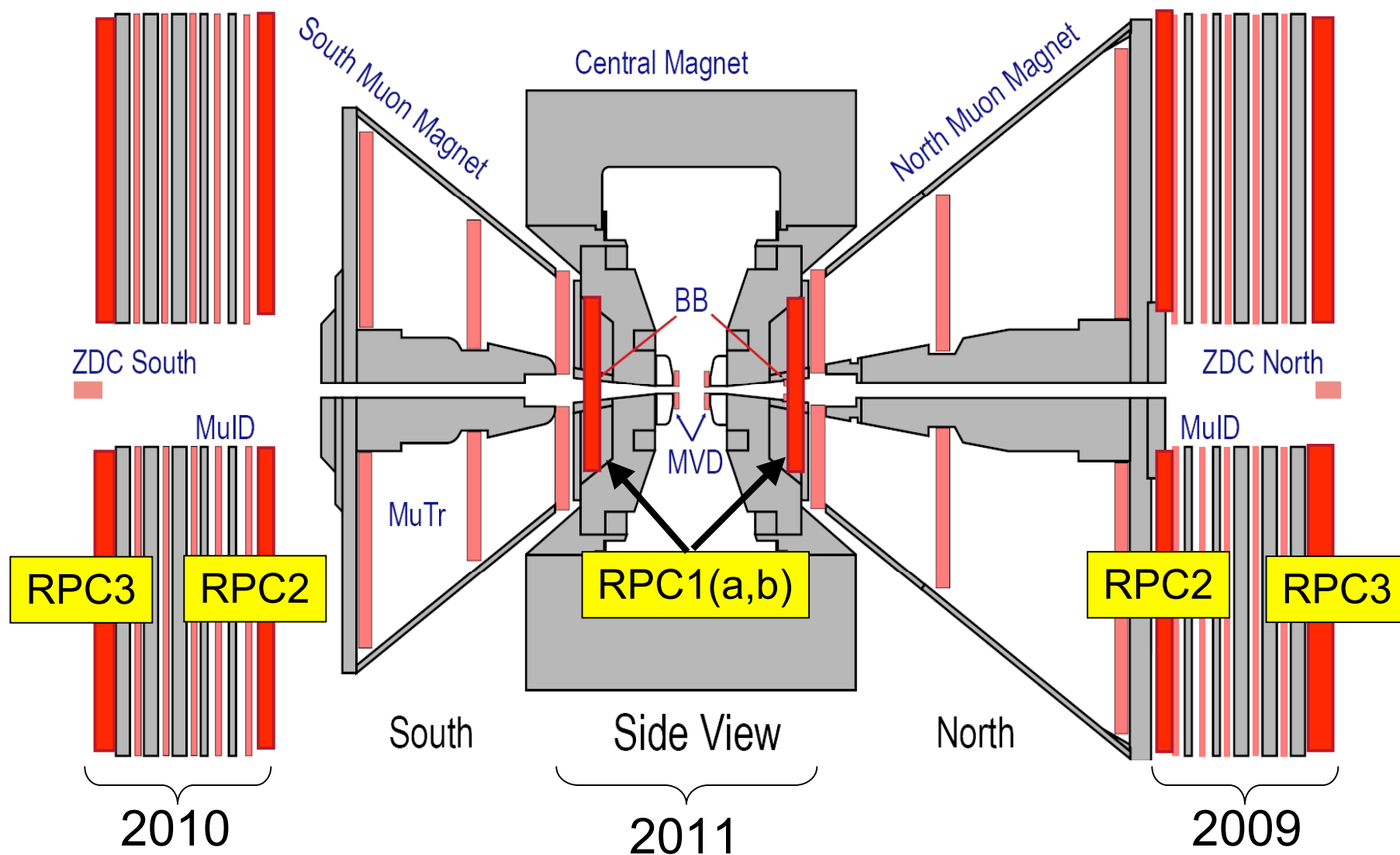
Experiment

- $\sqrt{s} = 500$ GeV polarized pp collisions
- Probe the **quark and anti-quark spin** contributions via high momentum muons from the W bosons
- Need to at least **increase rejection factor** of muon arms from **~500 to 6,000**
 - We aim to have a rejection factor of $\sim 10,000$



For more details refer to Byunsik Hong's Talk from Wednesday

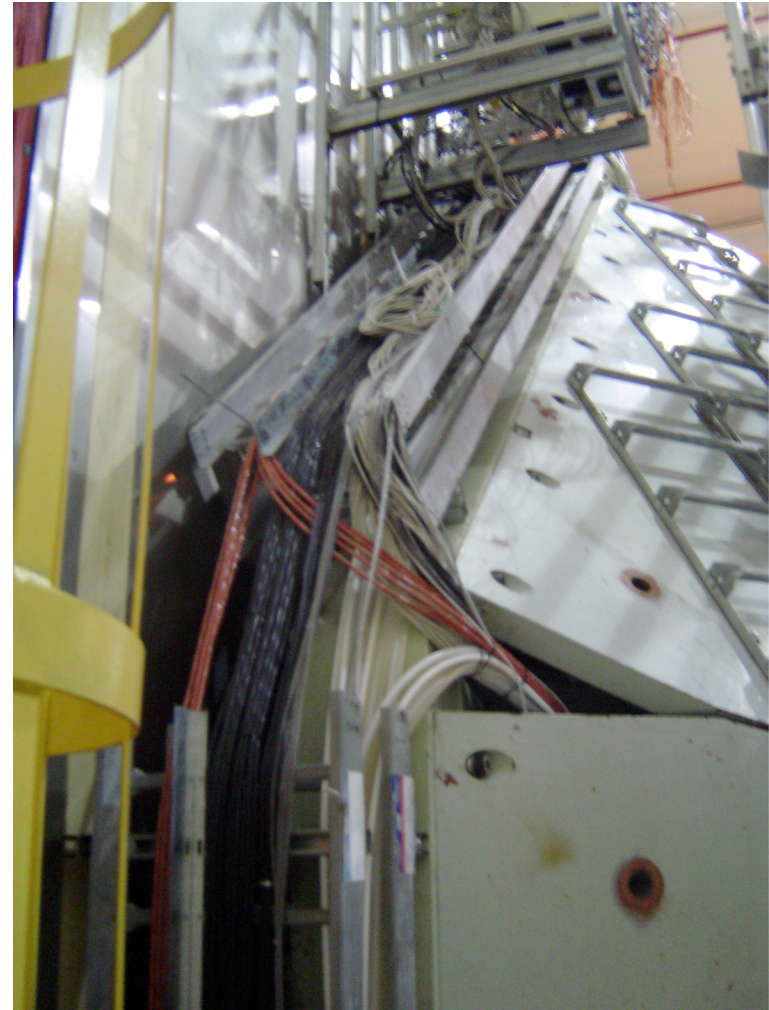
Scope of the PHENIX RPC Trigger Upgrade and Schedule



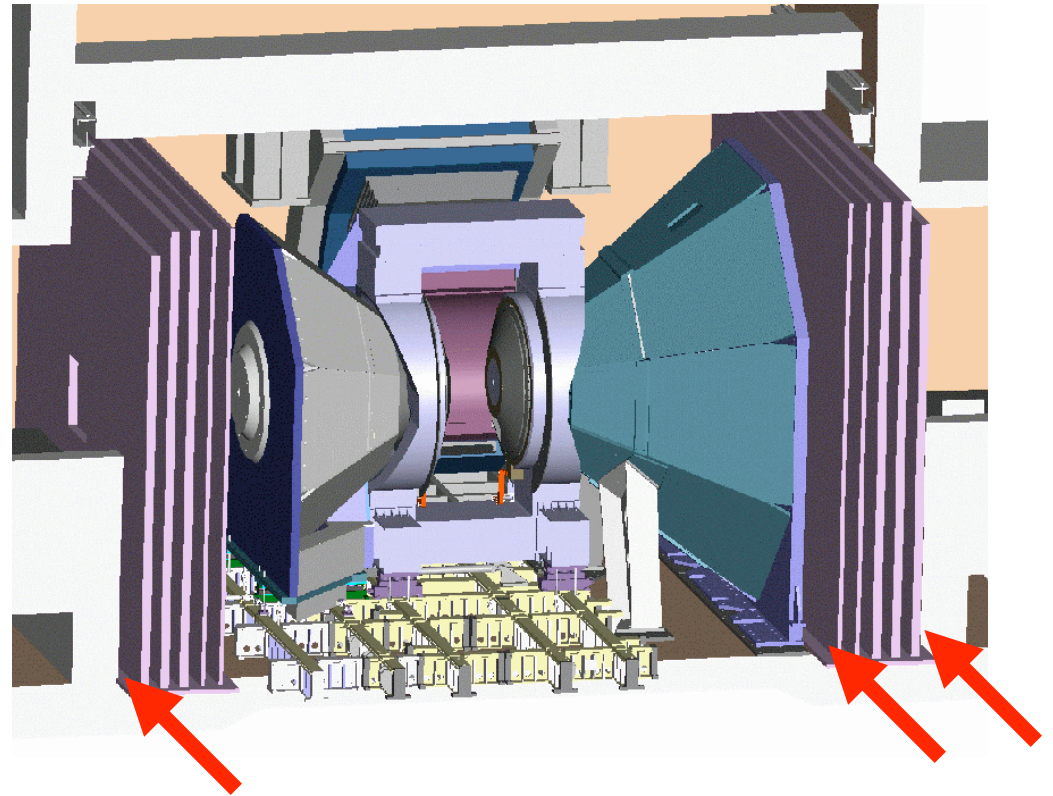
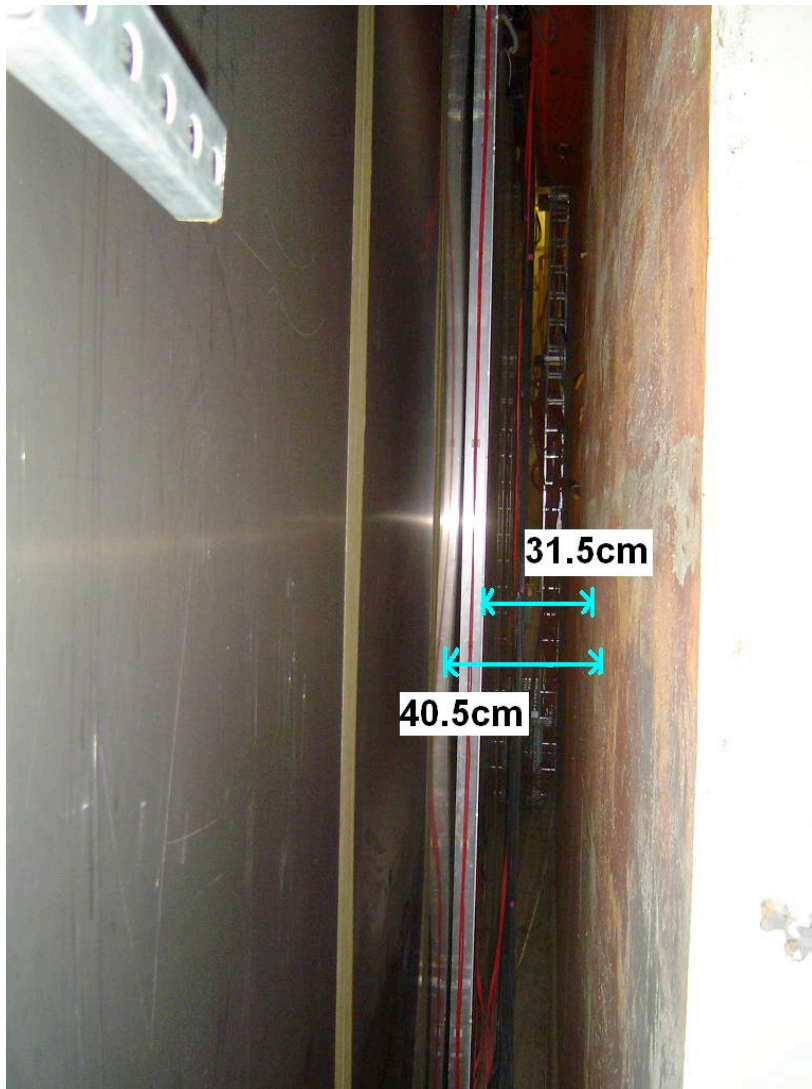
Integration

- Upgrading can be more challenging than initial construction!
- Existing infrastructure must be relocated
 - Cable trays
 - Rack platforms
 - Shielding blocks, ...
- Small gaps
 - Requires a thin detector design
 - Installation is in a confined space
 - Not easy to do any maintenance or repairs after installation.

Cable Trays Must be Moved

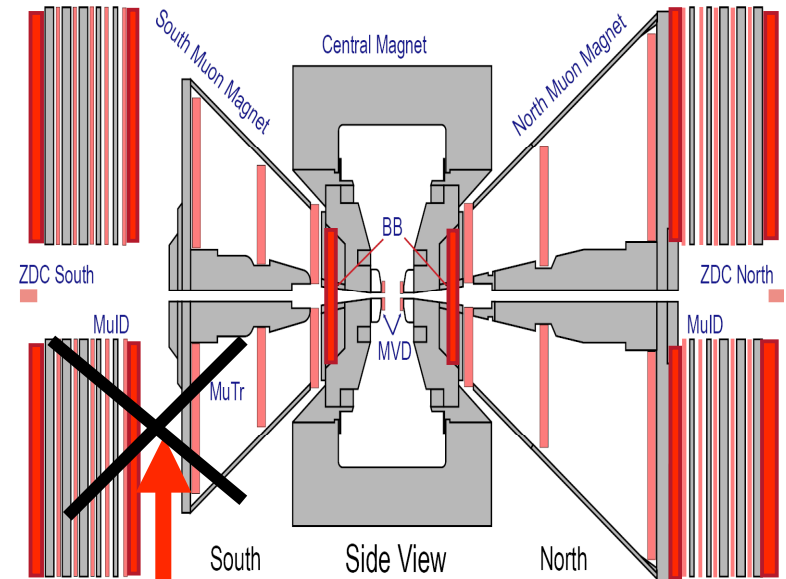
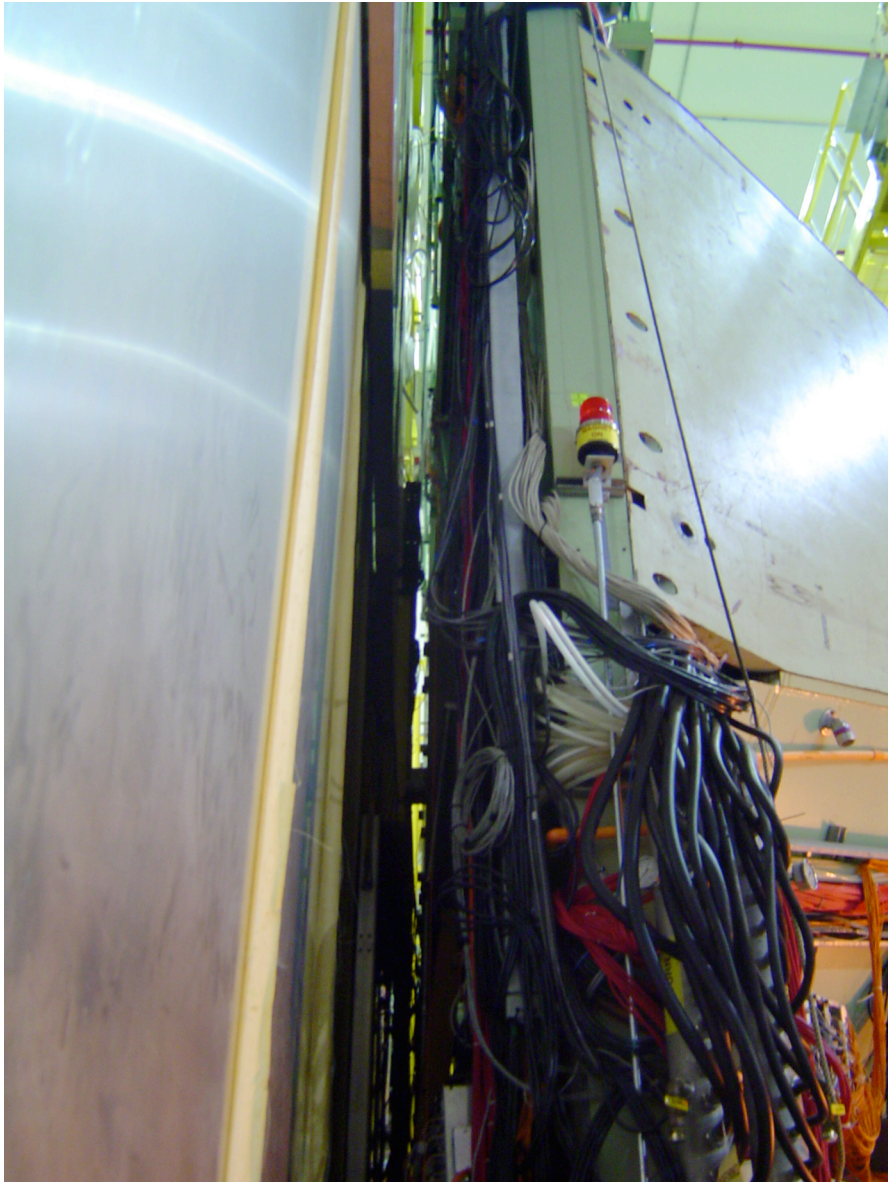


Narrow Gaps in Station 2 & 3



Some gaps are as small as
13 cm in places.

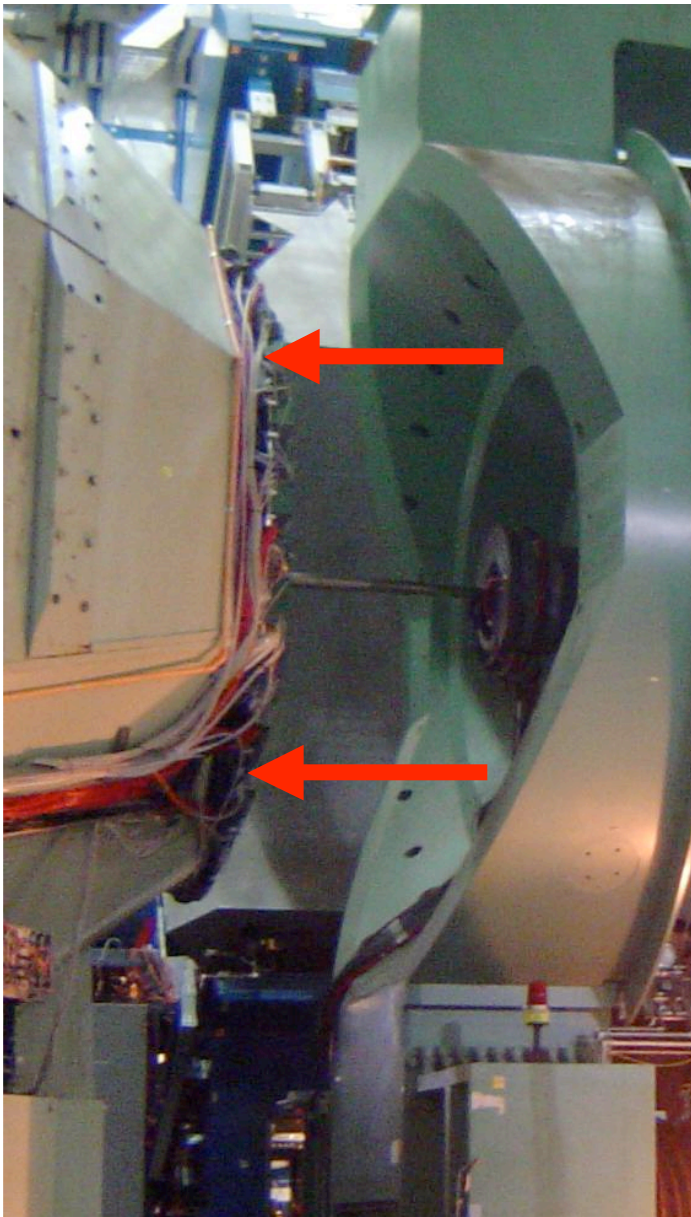
Even RPC2 South is a Challenge



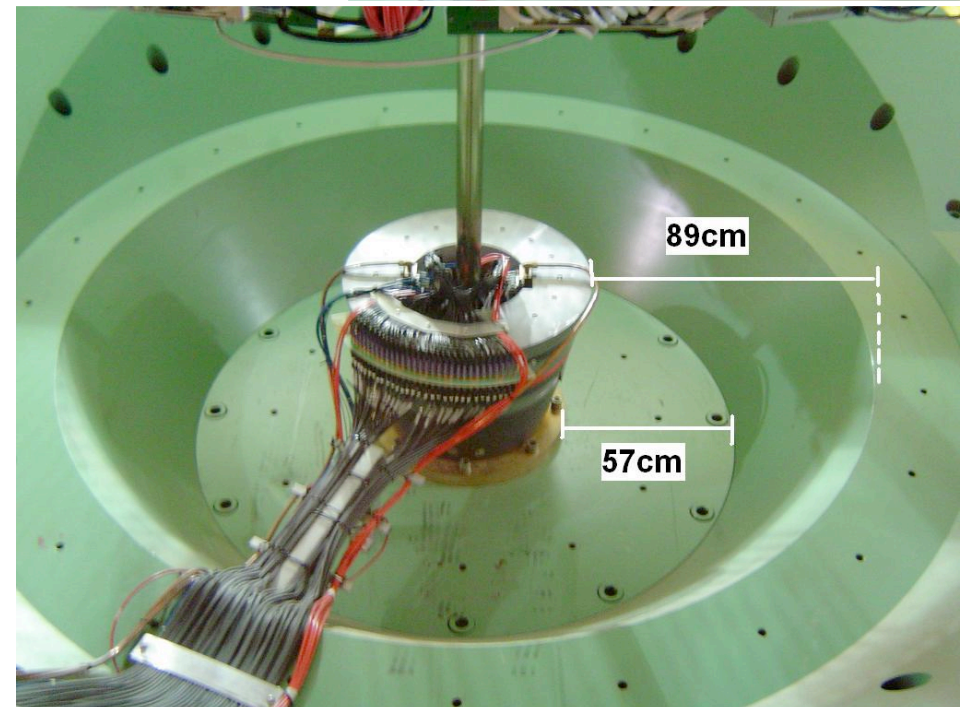
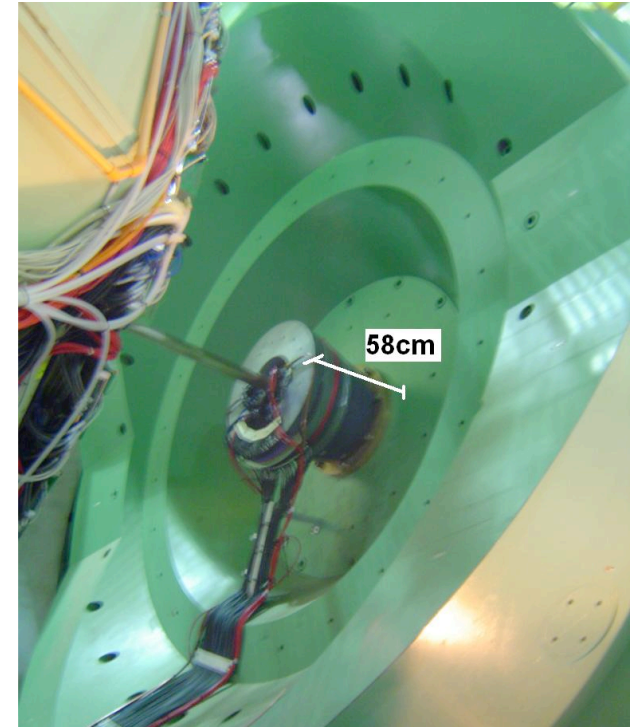
~~RPC2 South Gap is ~ 1.8m~~

... when the SMMis in data taking position. But during maintenance there are only cm's to spare.

Station 1



SMM Retracted
for maintenance



Station 3 limits Maximum RPC Module Size



Half Octant Mockup Test



PHENIX Design

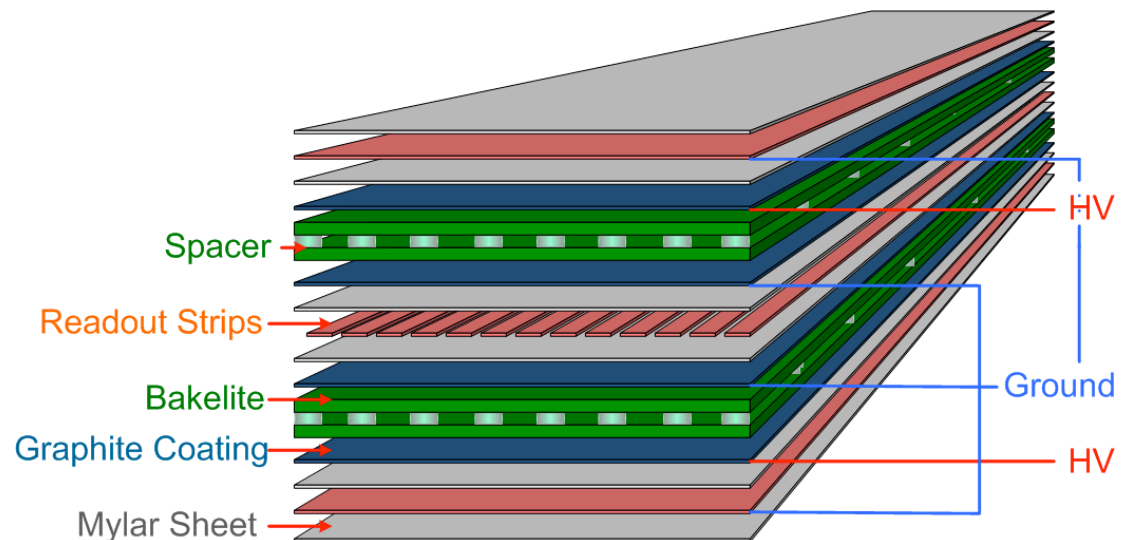
PHENIX RPC detector requirement

Efficiency	$> 95\%$
Time resolution	$\leq 3 \text{ ns}$
Average cluster size	$\leq 2 \text{ strips}$
Rate capability	0.5 kHz/cm^2
Number of streamers	$< 10 \%$

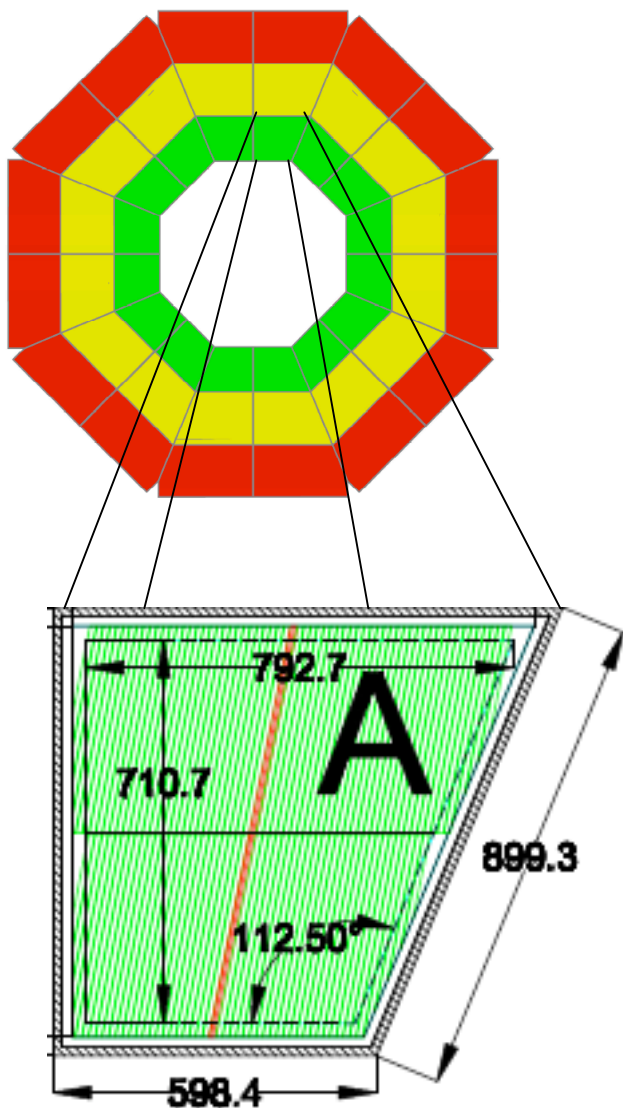
Our requirements are
Very similar to those
Of the CMS end caps.

Therefore we are taking
advantage of their work.

Thanks!



PHENIX Readout Planes



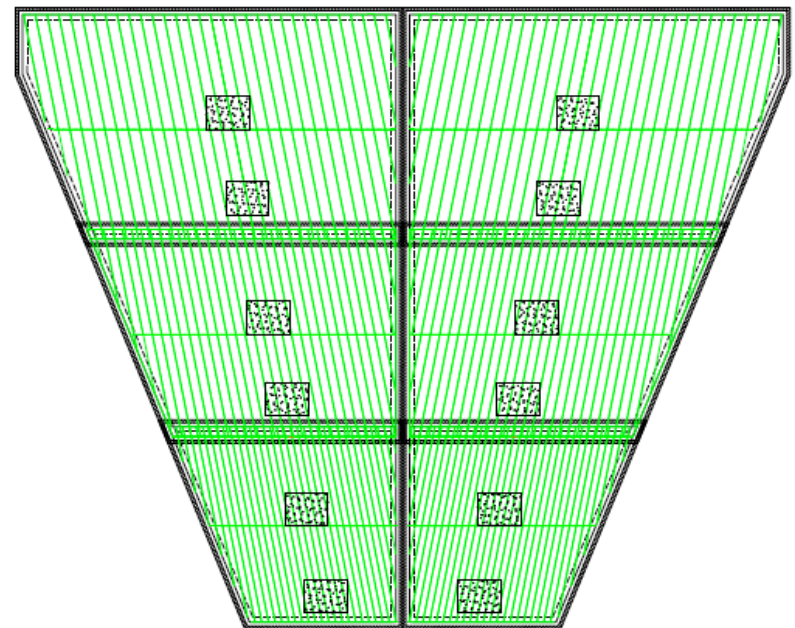
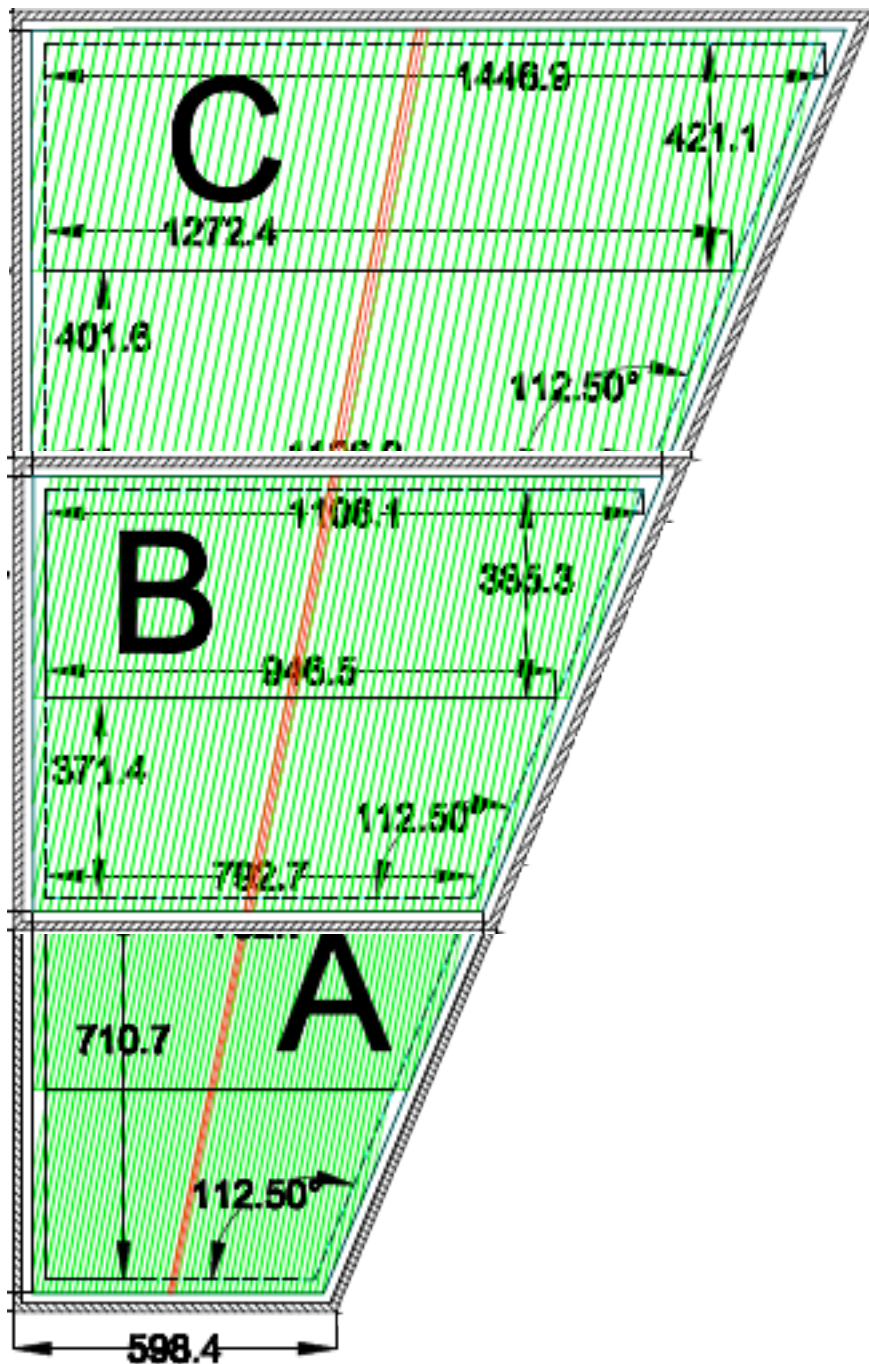
- Each double gap module contains 1 'pseudo-radial' readout plane
- Read out occurs at inner and outer radius of unterminated strips

**RPC1: 32 RPC detector modules
(768 readout channels)**

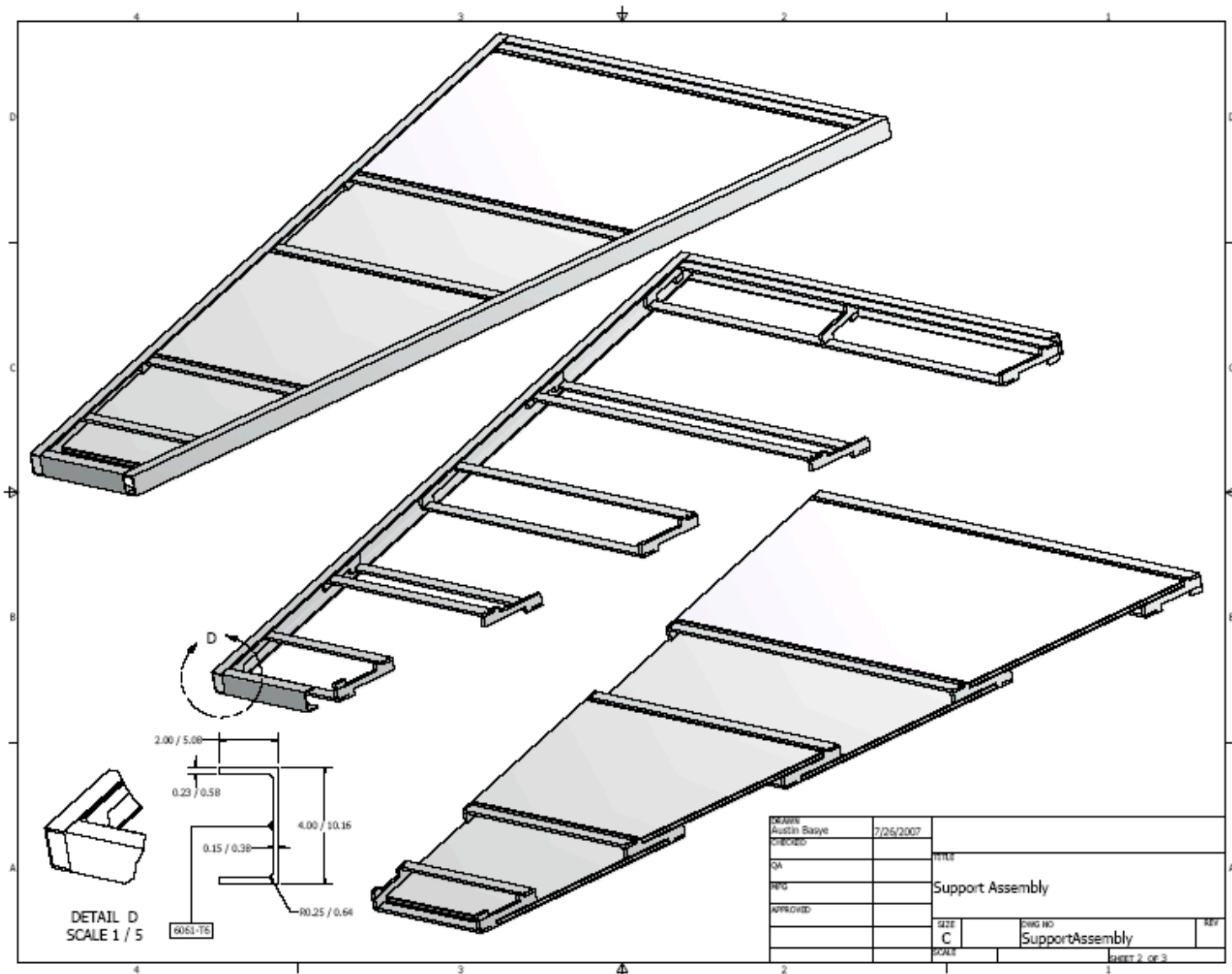
**RPC2: 128 RPC detector modules
(15392 readout channels)**

**RPC3: 96 RPC detector modules
(11488 readout channels)**

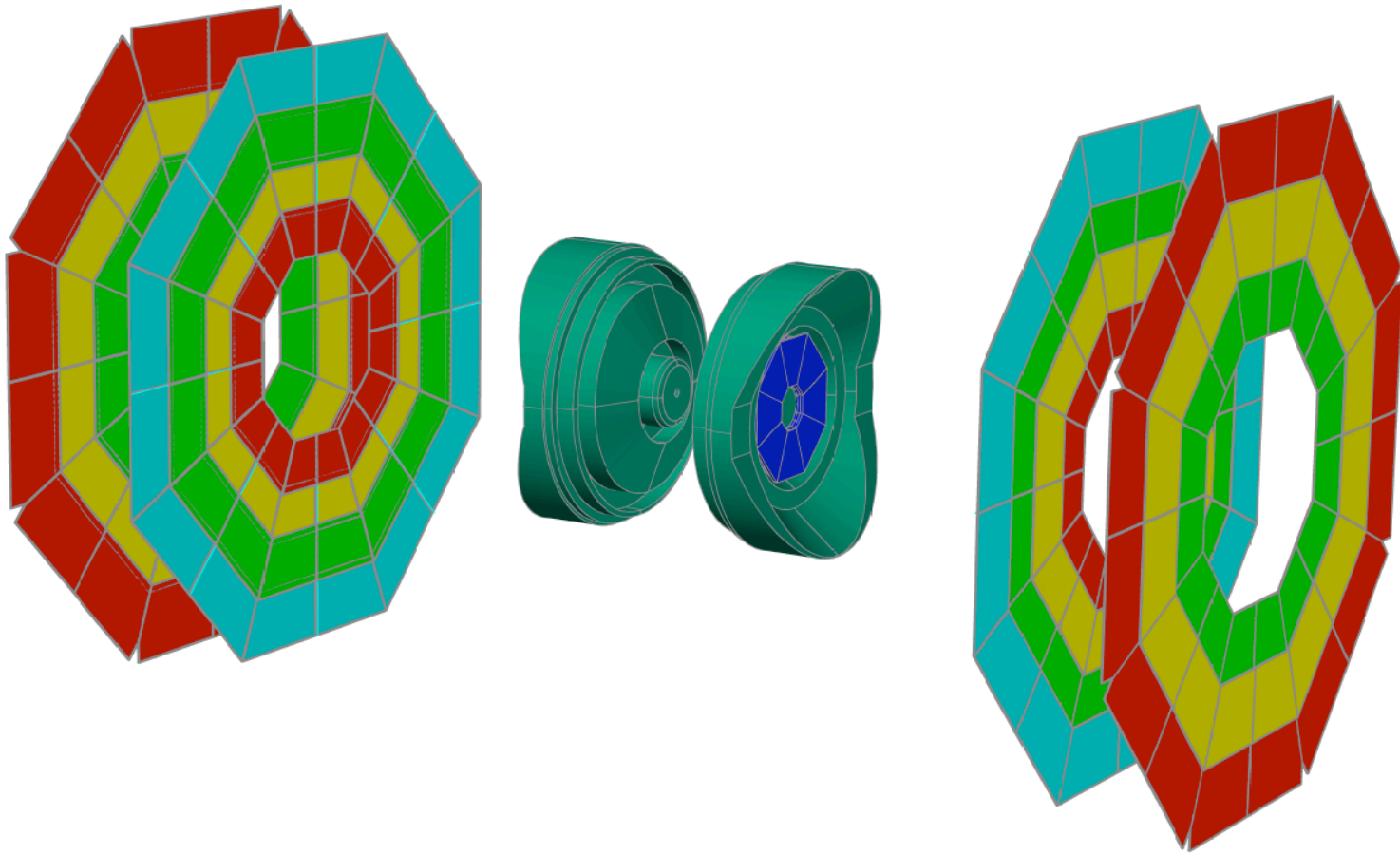
Half Octants and Octants



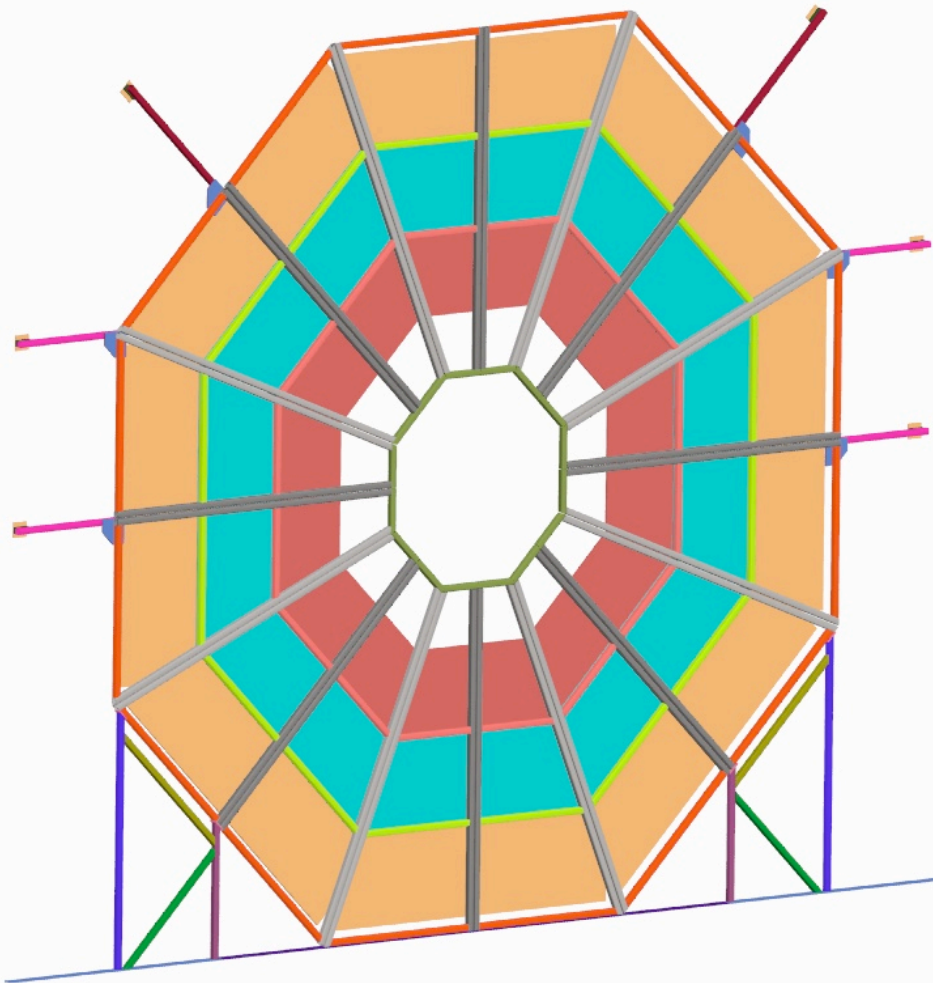
Half octant construction



Complete PHENIX RPC System (hanging in space)

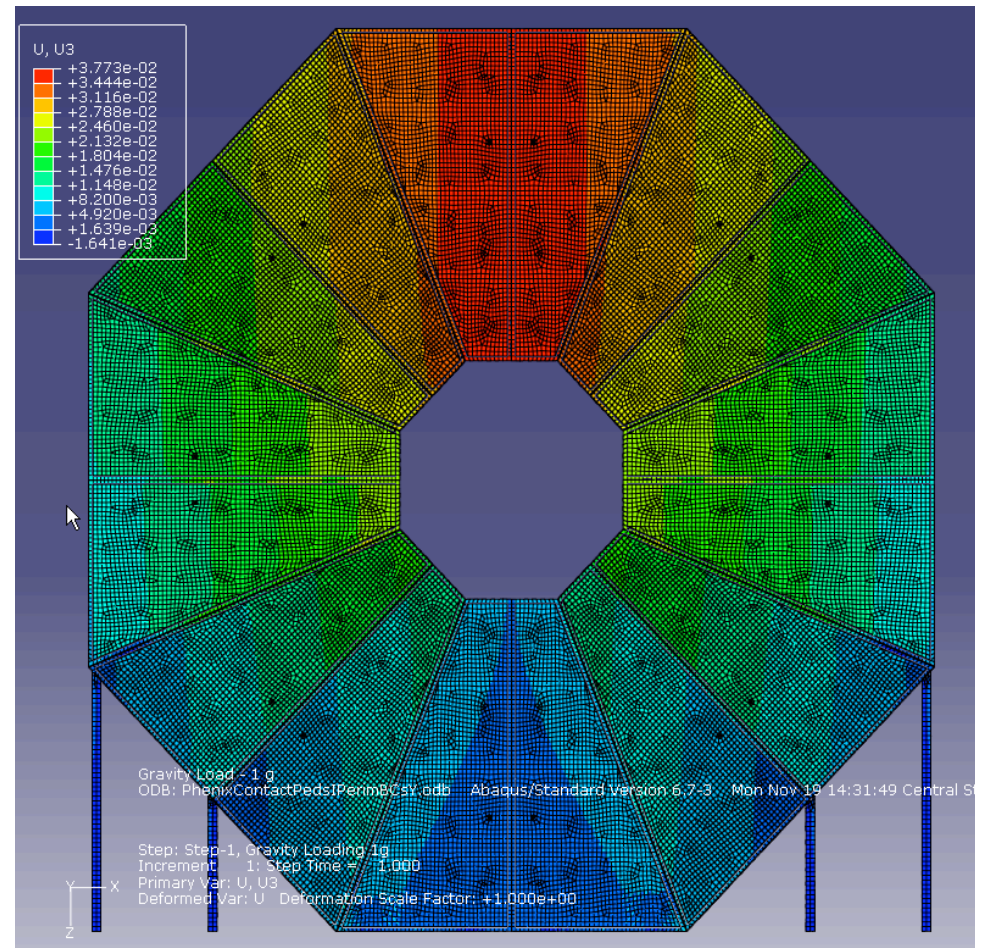
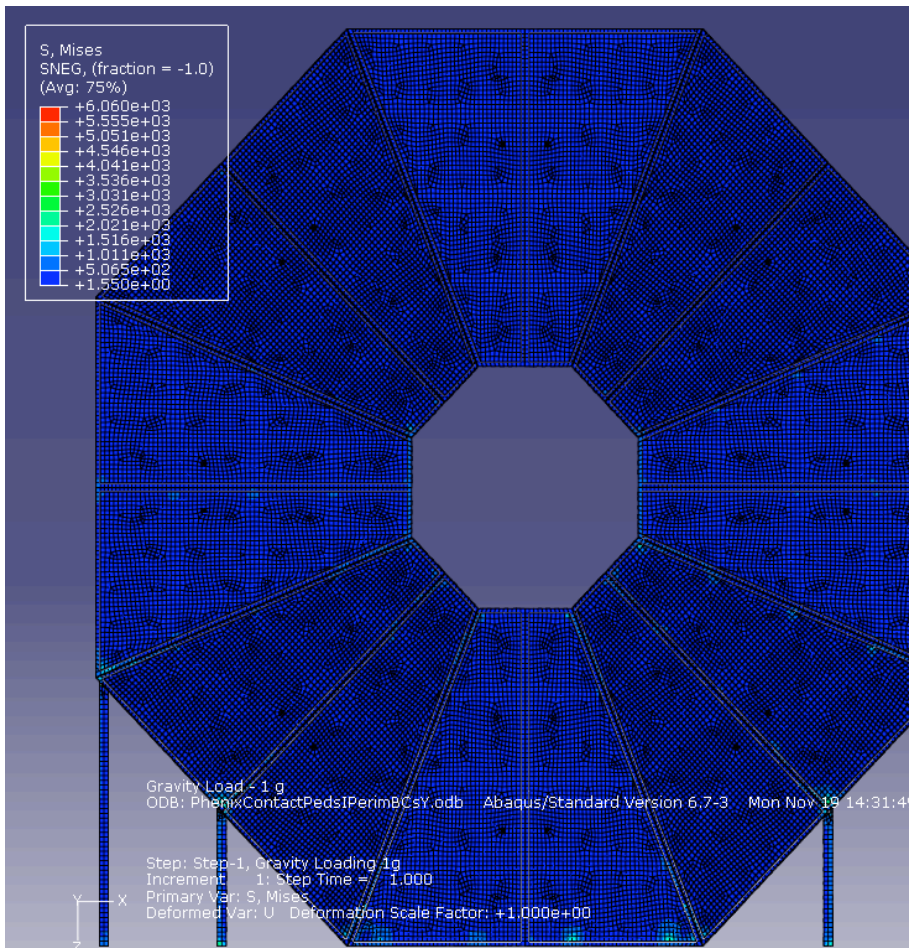


RPC2 and RPC 3 Installation Plan



- Structure is half octant frames attached at inner and outer radius and a pedestal.
- Initial finite element analysis of RPC2 and RPC3 structure has been completed.

Maximum Stress and Deflection are below acceptable levels



Flow Chart of RPC production for PHENIX



- Bakelites are produced and cut in Italy
- Gas gaps are produced at Korea University
- RPC frame & parts are procured in China (CIAE)
- Final assembly is done at BNL.

Italian Bakelite Production



- In December 2007, 54 1.3m x 2.8m “CMS quality” bakelite sheets were produced by the Italian bakelite company for the first time in several years.
- In January a group from PHENIX traveled to Pavia and with lots of help from our CMS friends tested the bakelite.
- Thanks to Paolo Vitulo, Giuseppe Iaselli, and Giuseppe Belli!



Bakelite Quality Control

The bakelite was tested

- acceptable resistivity

$$1 \cdot 10^{10} \Omega \cdot cm < \rho_{Average} < 6 \cdot 10^{10} \Omega \cdot cm$$

- uniform resistivity

$$\frac{\sigma}{\rho_{Average}} < 0.5$$

- thickness

$$2mm \pm 0.1mm$$

- smoothness

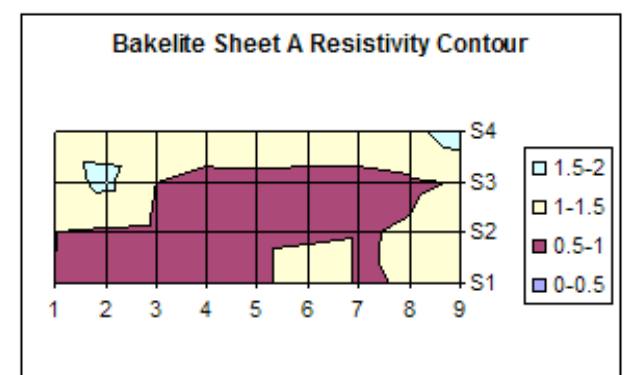
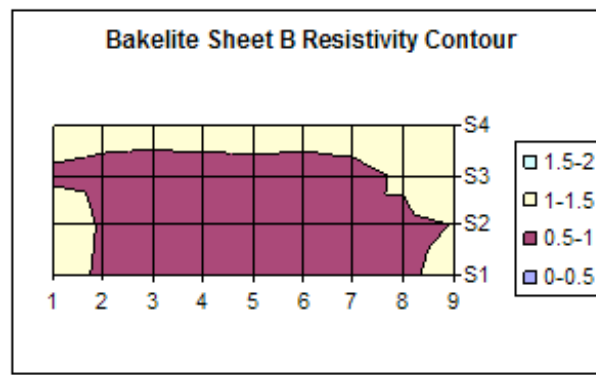
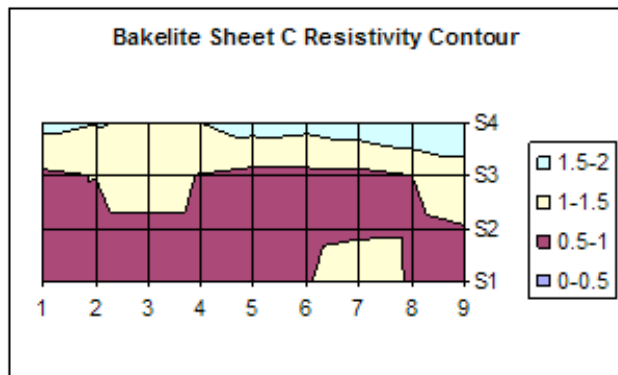
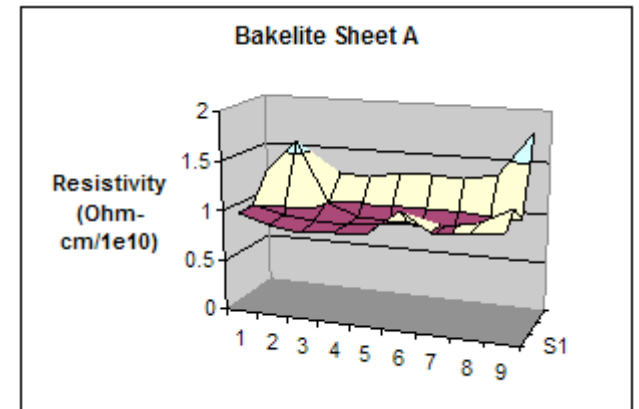
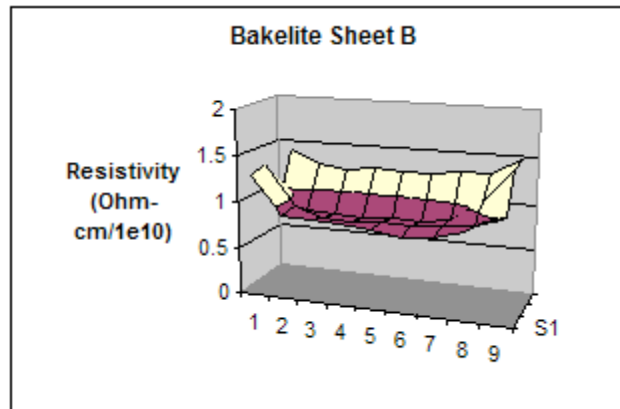
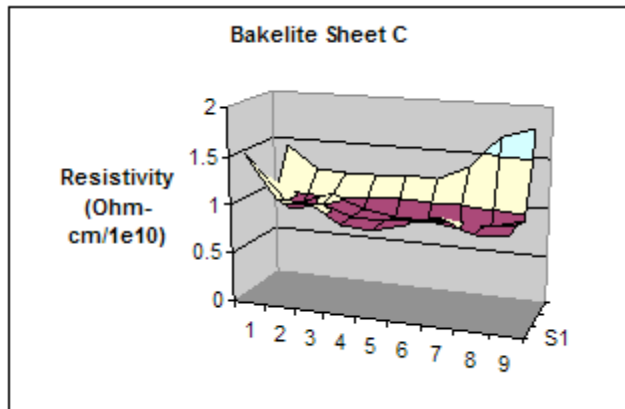
$$R_a < 0.2 \mu m$$

Detailed Destructive Testing

- 3 sheets were cut into 30 cm x 30 cm pieces and the resistivity was measured at 4 points on each little piece.
- Other qualities were spot checked.
- All 3 sheets were found to meet our specifications.



Bulk Resistivity Measurement



Average 1.08E+10 Ωcm
 Standard Deviation 2.38E+09
 Standard Deviation /Average 0.220703

Average 1.022E+10 Ωcm
 Standard Deviation 2.253E+09
 Standard Deviation /Average 0.2204842

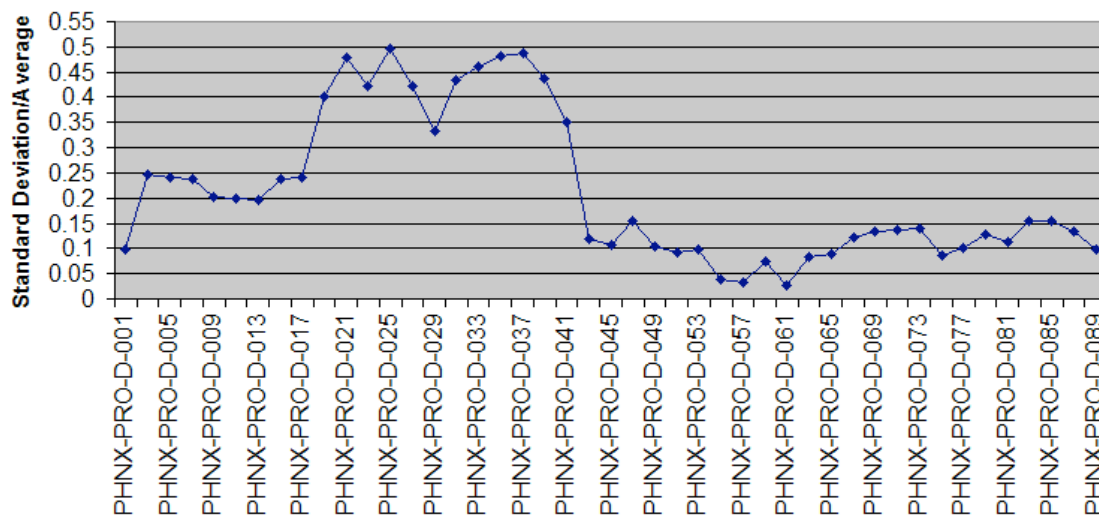
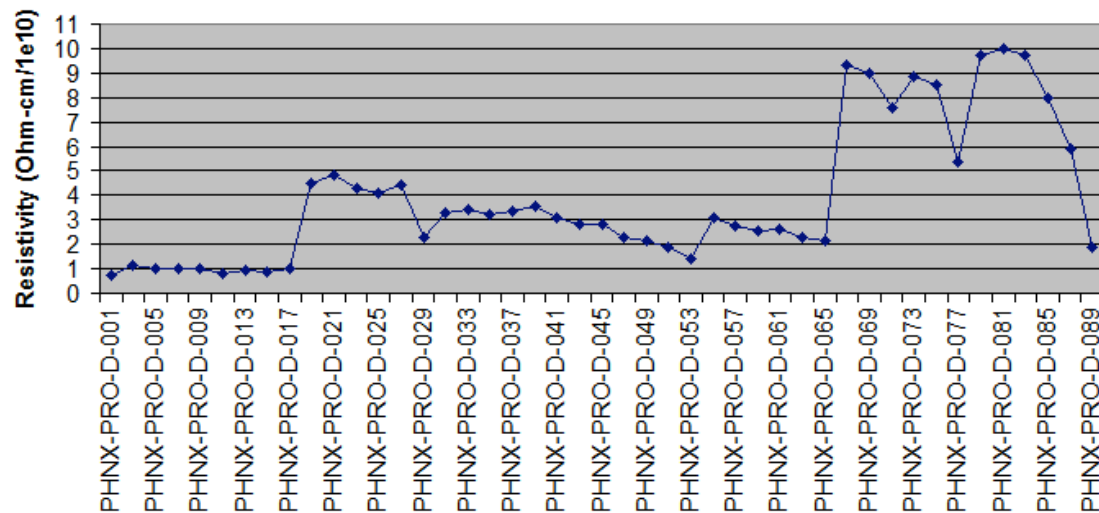
Average 1.08E+10 Ωcm
 Standard Deviation 2.2E+09
 Standard Deviation /Average 0.202451

Testing the other 51 sheets

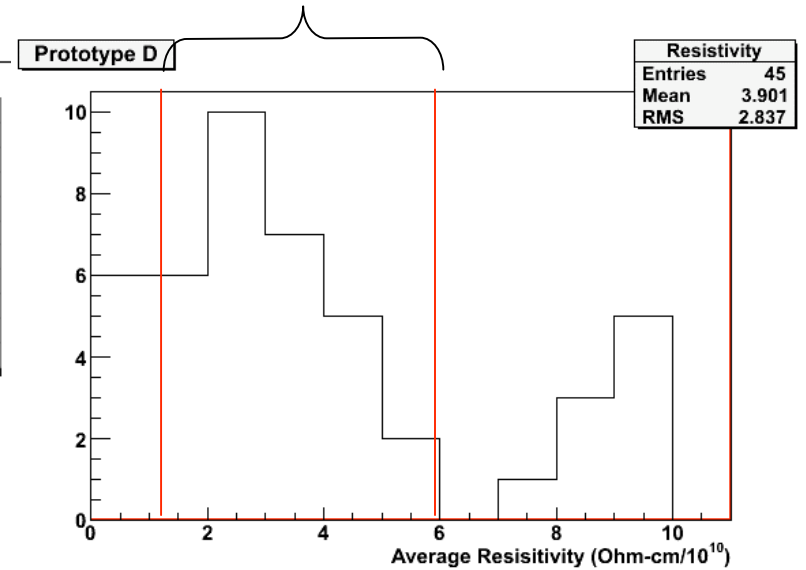
- The remaining 51 sheets were tested:
 - Bulk resistivity at 6 points on the perimeter.
 - Spot checked for other specifications.
- Results:
 - 6 produced with the wrong thickness (2.2mm)
 - 6 produced with average resistivity $< 10^{10} \Omega \text{ cm}$
 - 9 produced with average resistivity $> 6 \times 10^{10} \Omega \text{ cm}$
 - 30 sheets met our specifications
- Total Yield was 33/54 sheets or ~60%.

Results for Prototype D Sheets

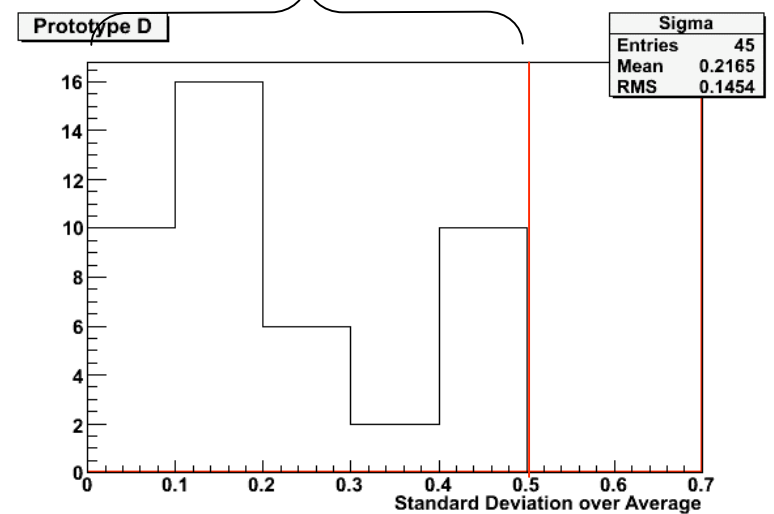
6 measurements on each plate—3 per side



Good



Good



Flow Chart of RPC production for PHENIX



- ▶ Bakelites are produced and cut in Italy
- ▶ Gas gaps are produced at Korea University
- ▶ RPC frame & parts are procured in China (CIAE)
- ▶ Final assembly is done at BNL.

The diagram is a detailed site plan of the ASU Medical Center, showing the layout of the tent, nitrogen distribution rack, and various storage areas. The plan is oriented with North at the top.

Tent Area (Top): A large rectangular area labeled "TENT 40' x 28'". Inside the tent, there are several tables and equipment:

- Tables:**
 - Two "Clean Rm" tables, each 8' x 8'.
 - Two "Sterile Table" units, each 8' x 8'.
 - Two "Device Table" units, each 8' x 8'.
 - Two "Open Table" units, each 8' x 8'.
 - Two "Clean Rm" tables, each 8' x 8'.
 - Two "Sterile Table" units, each 8' x 8'.
 - Two "Device Table" units, each 8' x 8'.
 - Two "Open Table" units, each 8' x 8'.
- Equipment:**
 - Two "2x17' Clean Rm" units.
 - Two "2x17' Clean Rm" units.
 - Two "2x17' Clean Rm" units.
 - Two "2x17' Clean Rm" units.

Nitrogen Distribution Rack (Middle): A large rectangular area labeled "NITROGEN DISTRIBUTION RACK FOR CHAMBERS IN STORAGE". It contains several storage units:

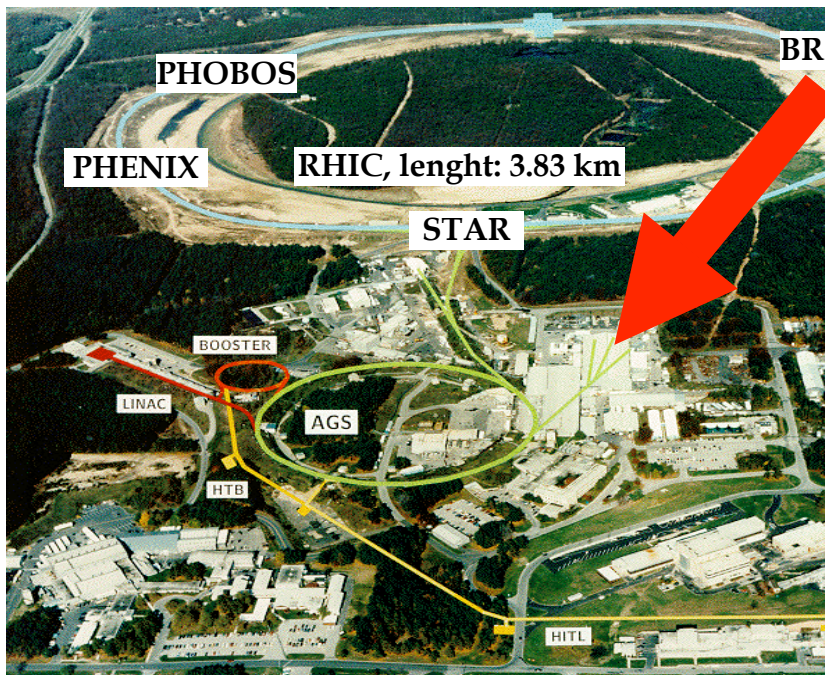
- Two "HALF DETANT ASSEMBLY TABLE 4.3' x 8.2'".
- Two "FRAME HARDWARE STORAGE" units.
- Two "FRAME HARDWARE STORAGE" units.
- Two "FRAME HARDWARE STORAGE" units.
- Two "FRAME HARDWARE STORAGE" units.

ASU Medical Center (Bottom): The main building of the ASU Medical Center, showing various rooms and corridors. Key areas include:

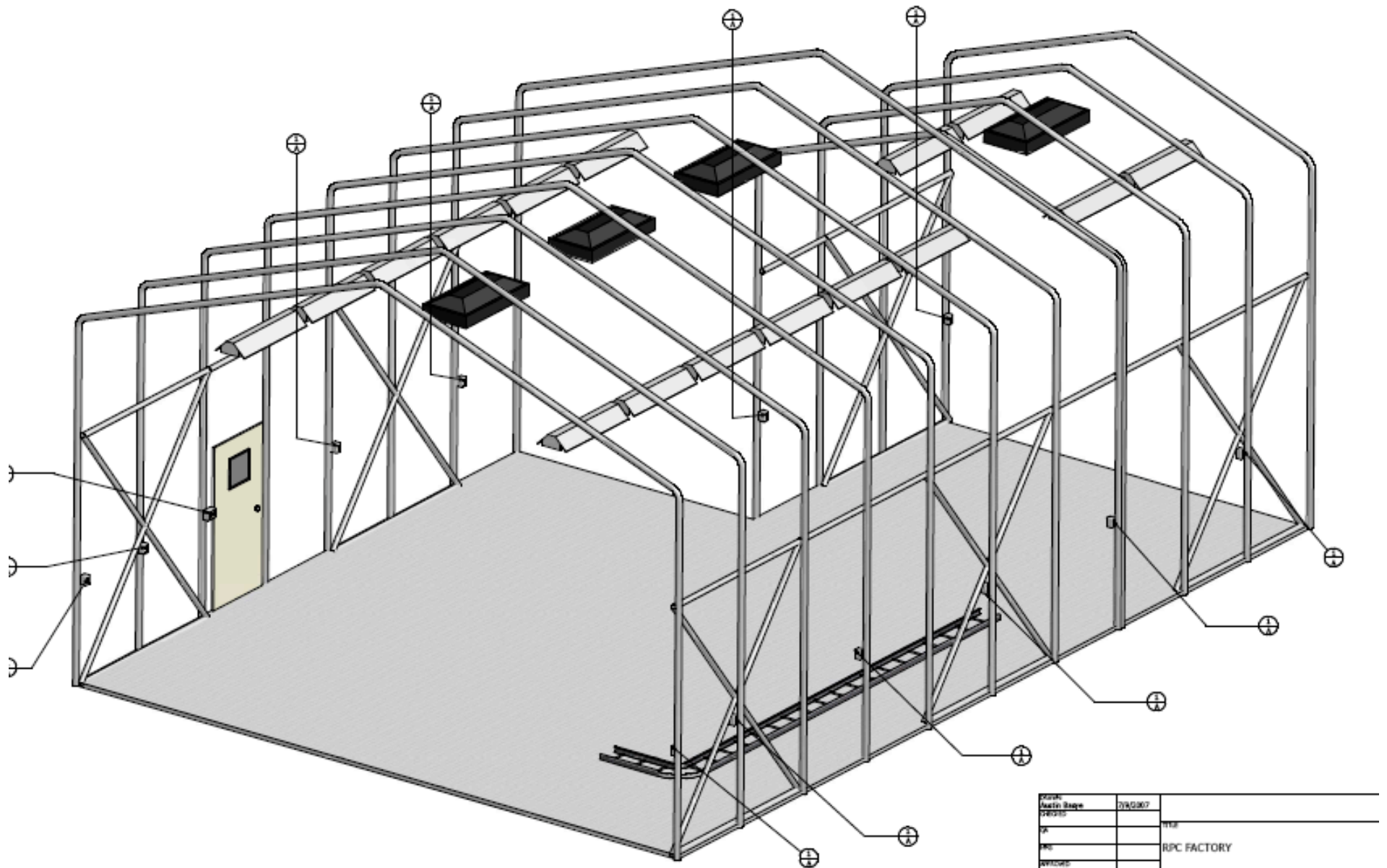
- ASU Medical Center:** The main building, with various rooms and corridors.
- ASU Medical Center:** The main building, with various rooms and corridors.
- ASU Medical Center:** The main building, with various rooms and corridors.

Other Labels:

- NITROGEN LINE:** A line running horizontally across the middle of the plan.
- NITROGEN RACK:** A rack located near the tent area.
- DEFLECTORS:** Located near the nitrogen rack.
- ASU Medical Center:** The main building, with various rooms and corridors.
- ASU Medical Center:** The main building, with various rooms and corridors.
- ASU Medical Center:** The main building, with various rooms and corridors.



Recycled PHENIX Tent

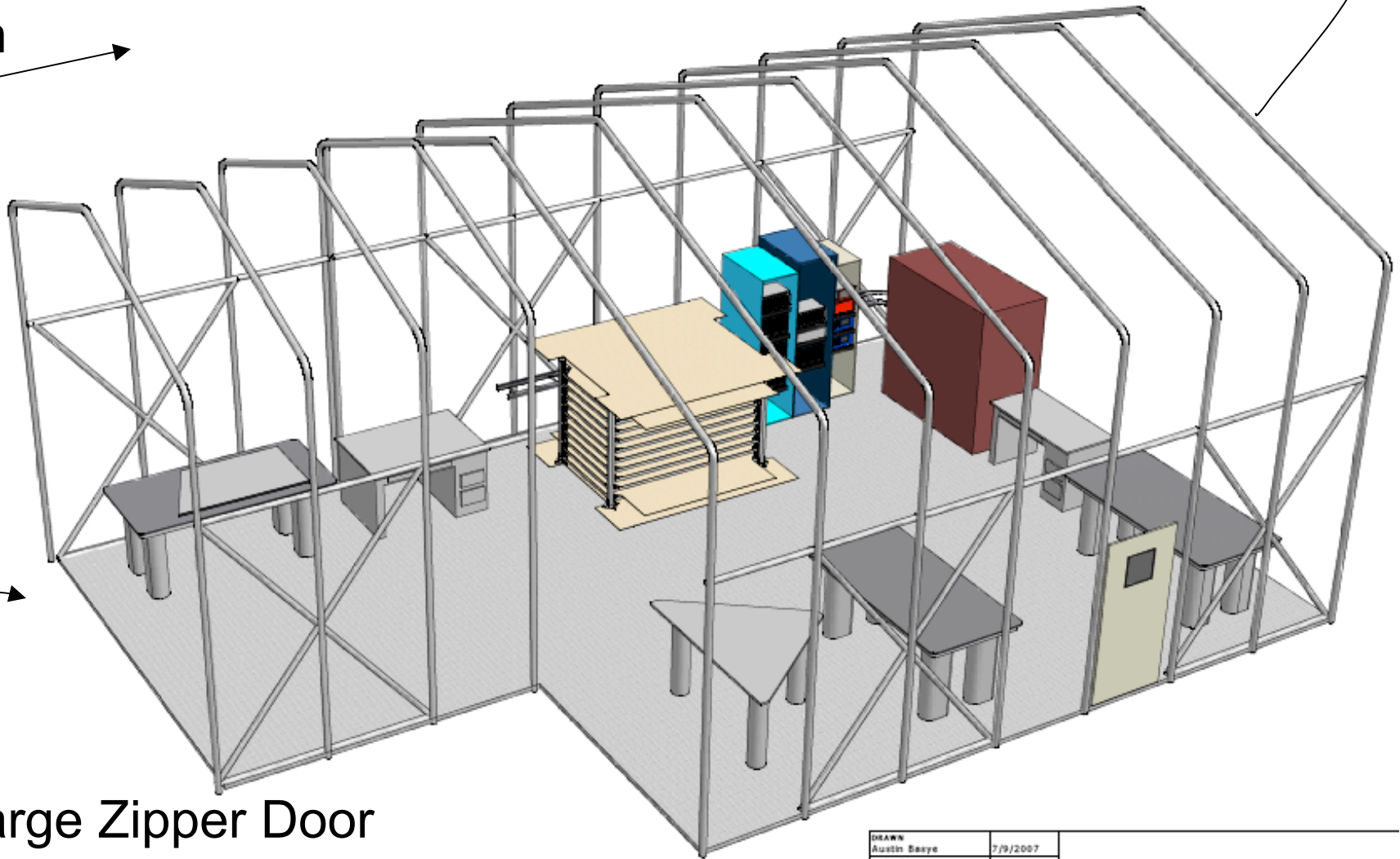


Factory Layout

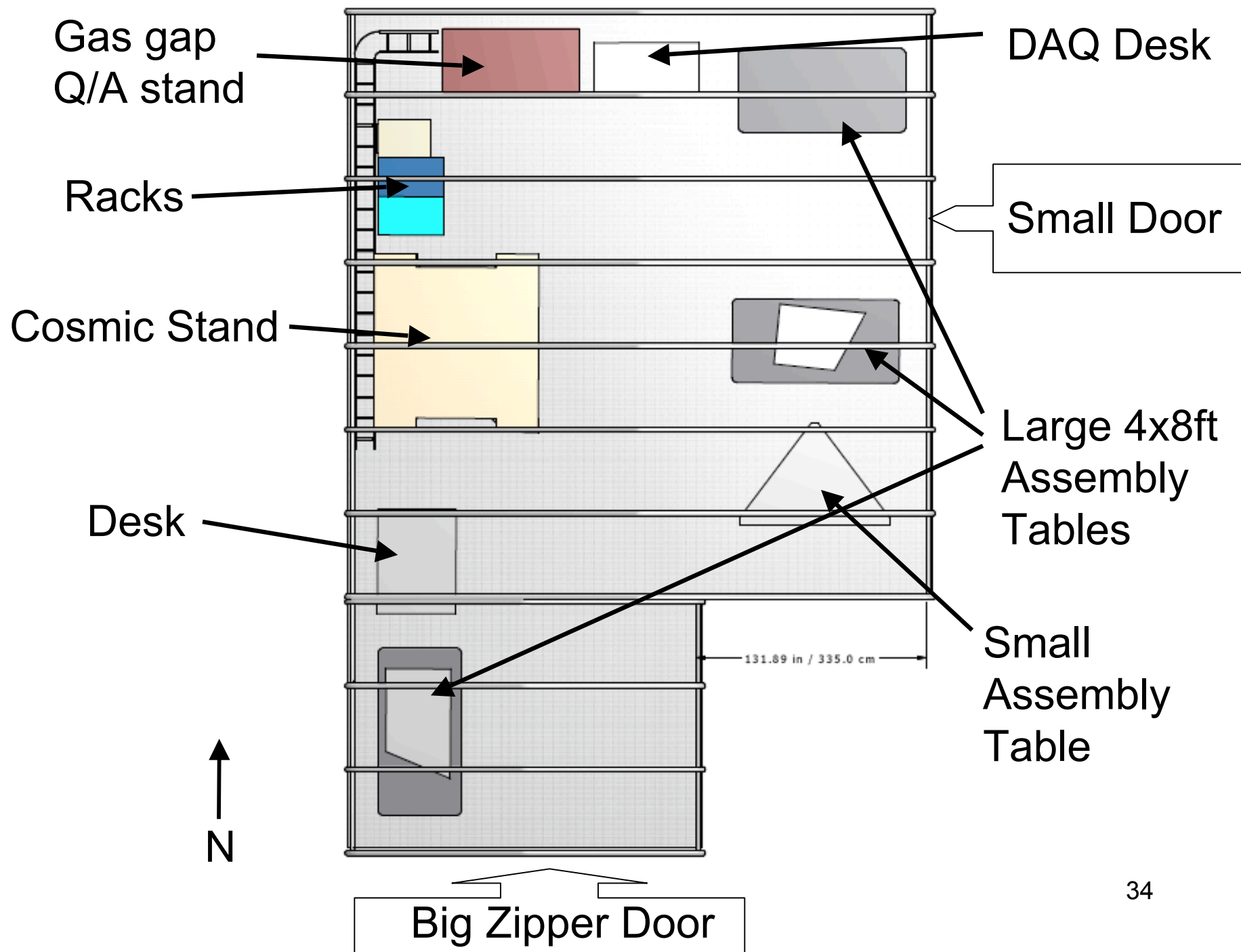
North

2 Large Zipper Doors
(Not used)


Large Zipper Door
(used for all large items)



DRAWN
Austin Beyer 7/9/2007

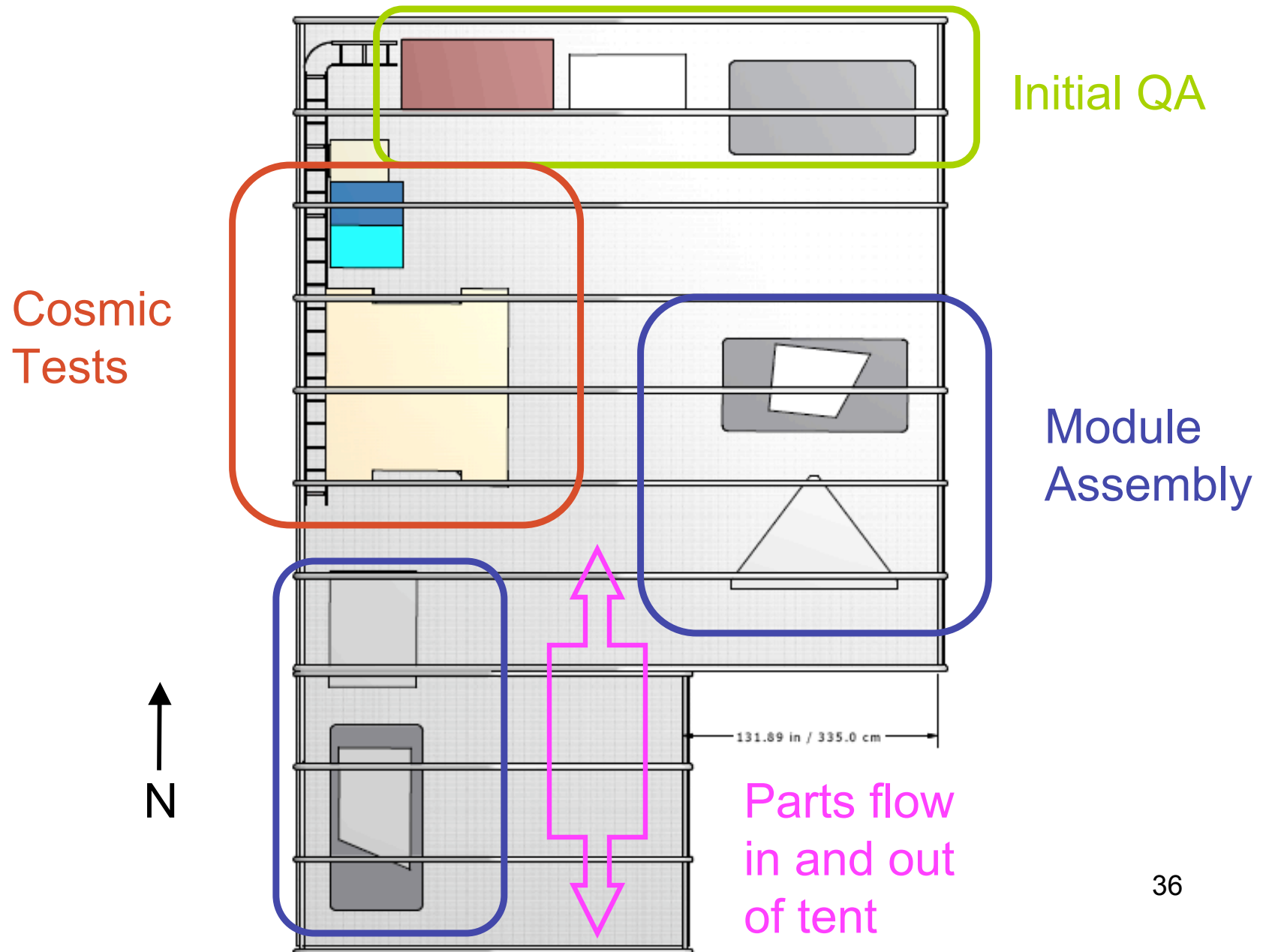


Factory Processes

- Inside
Tent
- 
1. Storage of Gas Gaps
 2. Initial QA of parts
 - a. Leak test, popped spacer test
 - b. Dark current test
 3. Module assembly
 4. Module QA
 - a. Leak test
 - b. Cosmic tests
 5. Storage of Modules
 6. Half Octant assembly
 7. Final QA of Half Octant
 8. Storage of Half Octants

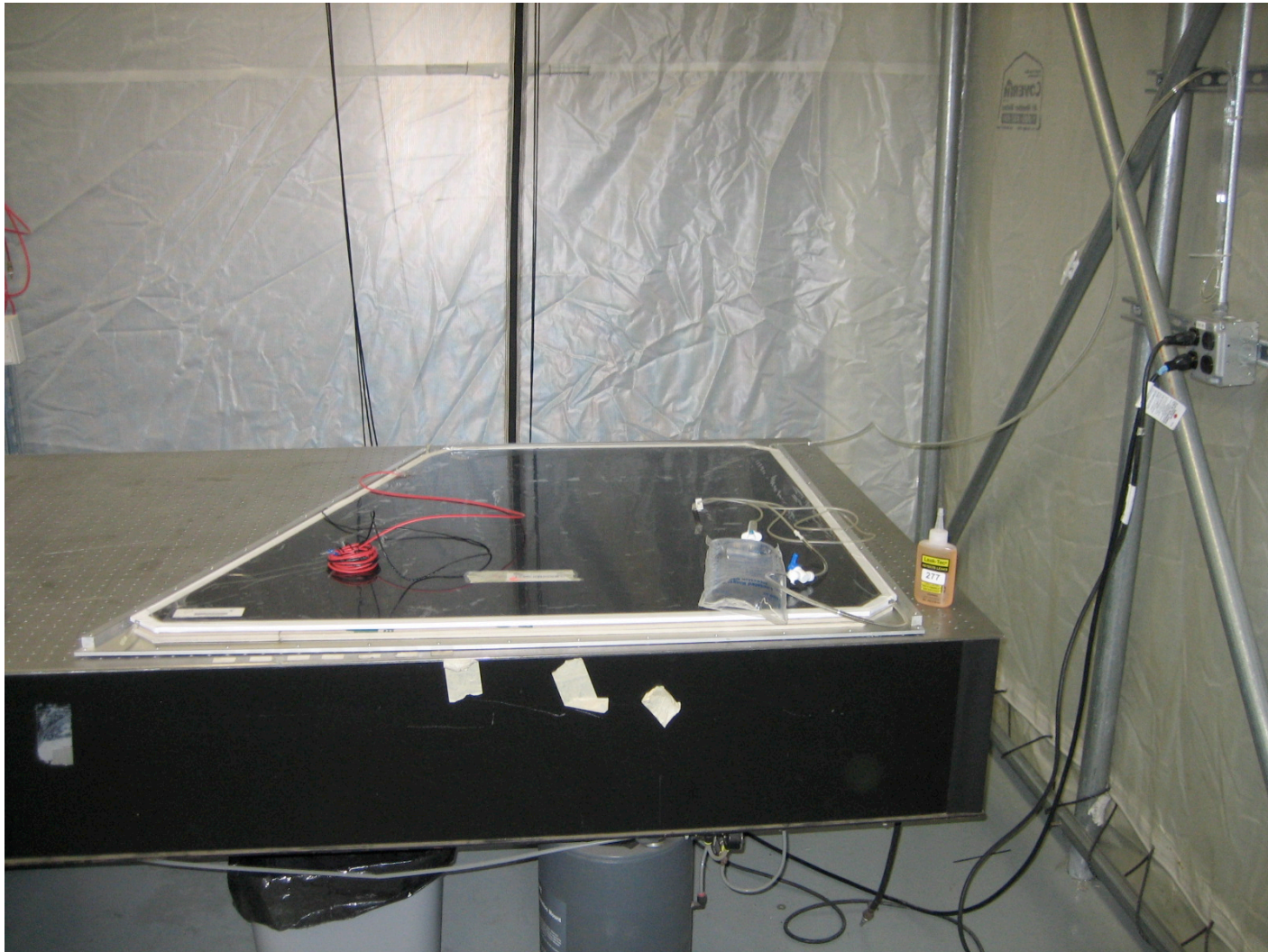
Tests and assembly modeled after CMS, Thanks to
Archana Sharma, Gabriella Pugliese,

Flow of work in the factory



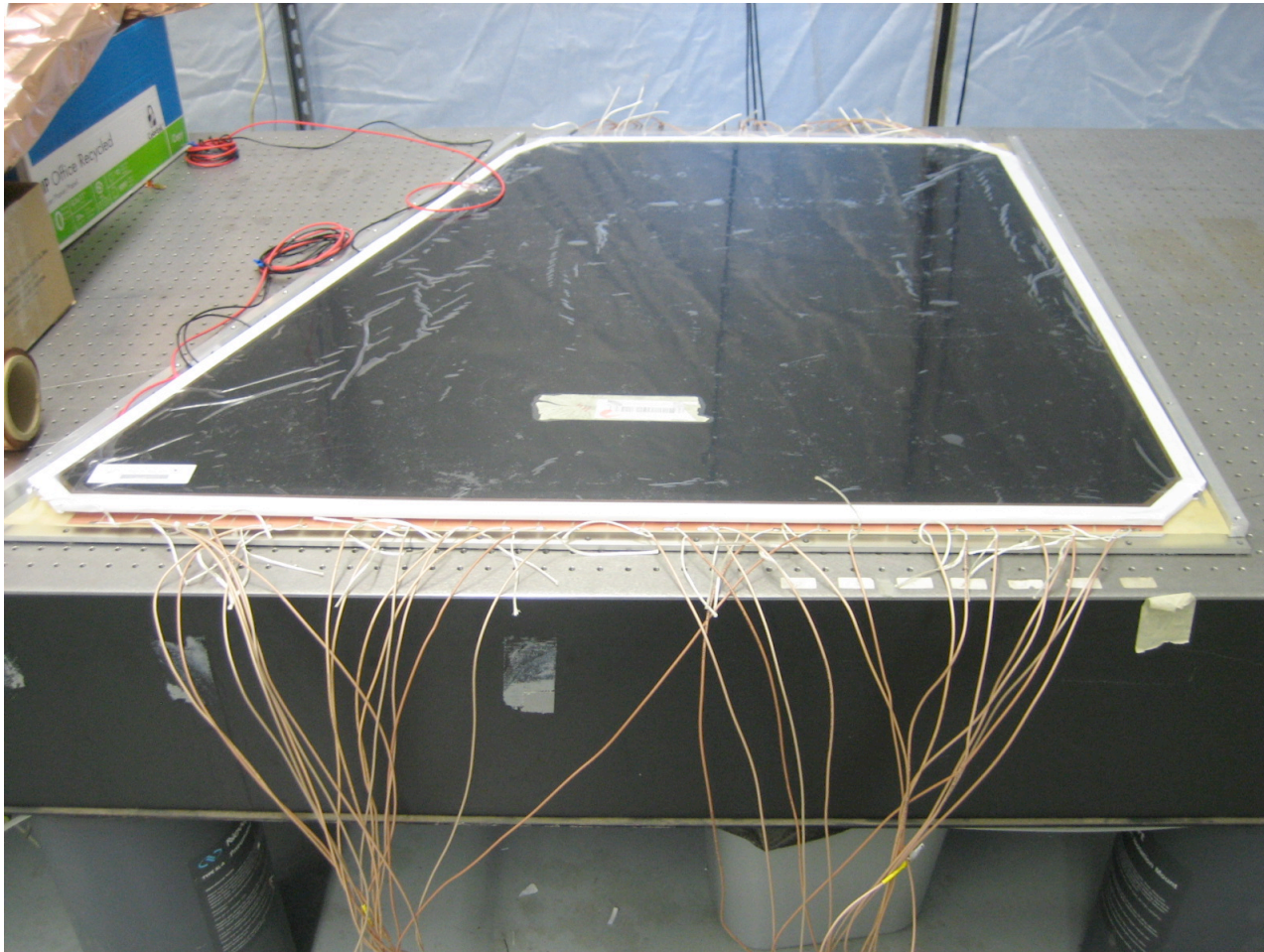
First Gap Tests

Parts for 3 prototype chambers are now at BNL



Prototype Assembly

Currently we are assembling 3 station 2 prototype modules.



Summary

- PHENIX is upgrading our muon trigger by adding 6 stations of RPCs.
- When this upgrade is completed, it will allow us to learn more about the spin structure of the proton.
- Much of our design had been patterned after the CMS end-cap RPCs.
- We expect to start assembling RPCs this summer so they can be installed next summer.
- Special thanks to the CMS RPC team and to the extended RPC community for all the help you've given us!